Effects of Historic Gold Mining on Water Quality and the Environment in California

Charles N. Alpers, Ph.D.

U.S. Geological Survey
California Water Science Center

Sacramento, CA

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Historic Gold Mining

- Tens of thousands of abandoned / inactive gold mines in California.
- Main contaminants of concern at hard-rock gold mines: arsenic, lead, and mercury.
- At placer gold mines, main contaminant is mercury.
- Some gold mines have acid mine drainage with elevated iron, aluminum, copper, zinc, cadmium, nickel, chromium, and other metals.

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Common Arsenic-rich Minerals in the Vicinity of Historic Gold Mines

Primary (Hydrothermal)

Pyrite
(FeS_2)
"Fool's Gold"
1-10 wt% As

Arsenopyrite (FeAsS)
46 wt% As

Secondary (Weathering)

Scorodite $FeAsO_4\ 2H_2O$
Tens of wt% As

Iron oxyhydroxide
("rust") containing arsenic
(up to 10 wt% As)

Jarosite $KFe_3(SO_4)_2(OH)_6$
Up to 1 wt% As

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Arsenic Speciation and Bioavailability

- Chemical species vital to hazard assessment
  - Arsenides, arsenites, arsenates – range in solubility
- Aqueous fluids critical (pathway into body)
  - drinking water (ingestion)
  - gastric and intestinal fluids (ingestion)
  - lung fluids (inhalation)
  - recreational water bodies (dermal absorption)
- USGS studies have assisted other agencies
  - Lava Cap Mine, Nevada County (USEPA/DTSC)
  - Mesa de Oro, Amador County (USEPA / DTSC)
  - Kelly / Rand / Johannesburg, Kern County (BLM)

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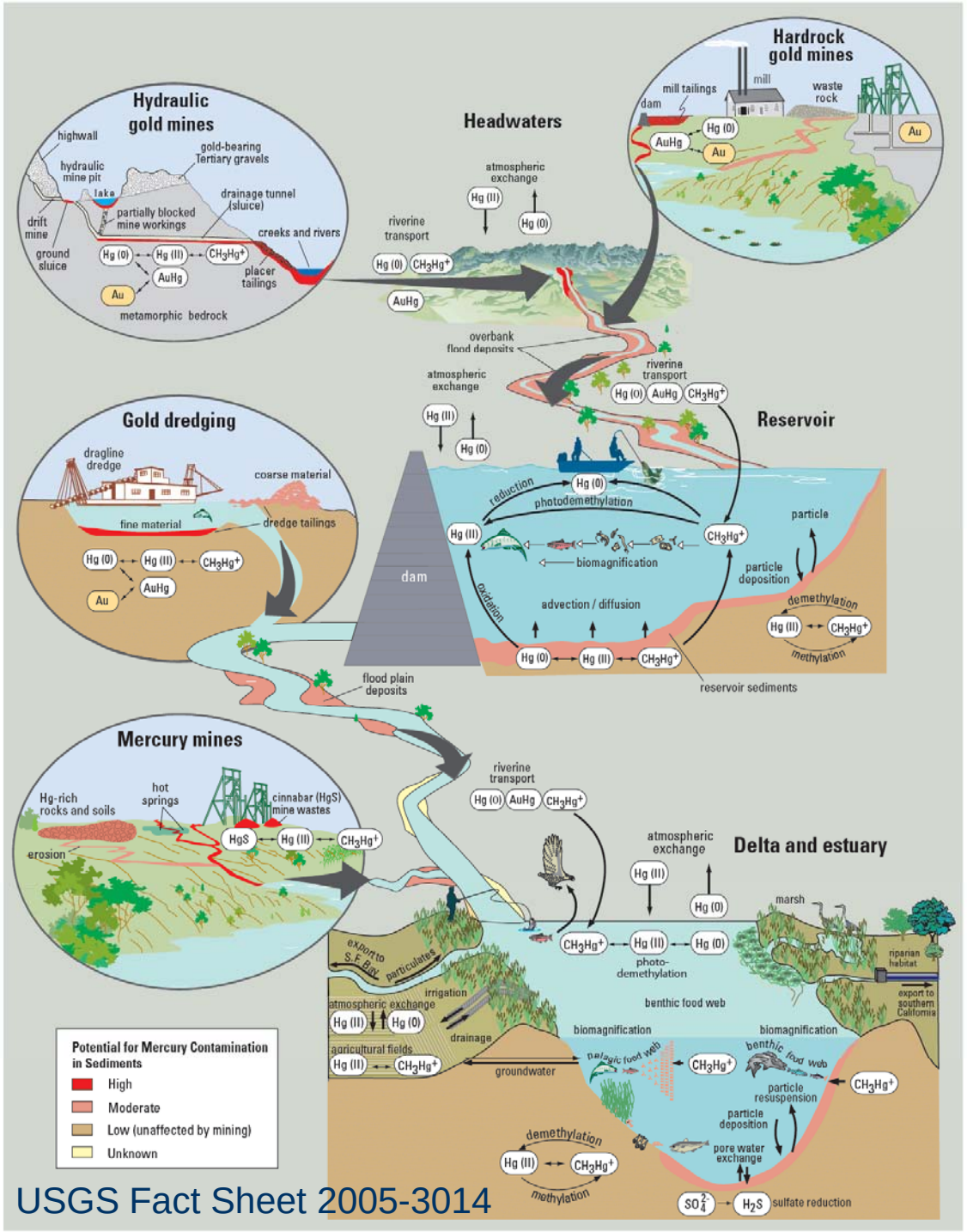

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Mercury Sources, Transport, and Bioaccumulation

ENVIRONMENTS:

- Mercury mines – Coast Ranges
- Hydraulic and hard-rock gold mines – Sierra Nevada
- Mountain streams above reservoirs
- Foothill reservoirs
- Rivers below reservoirs – gold dredging environments
- Floodplains
- San Francisco Bay-Delta estuary

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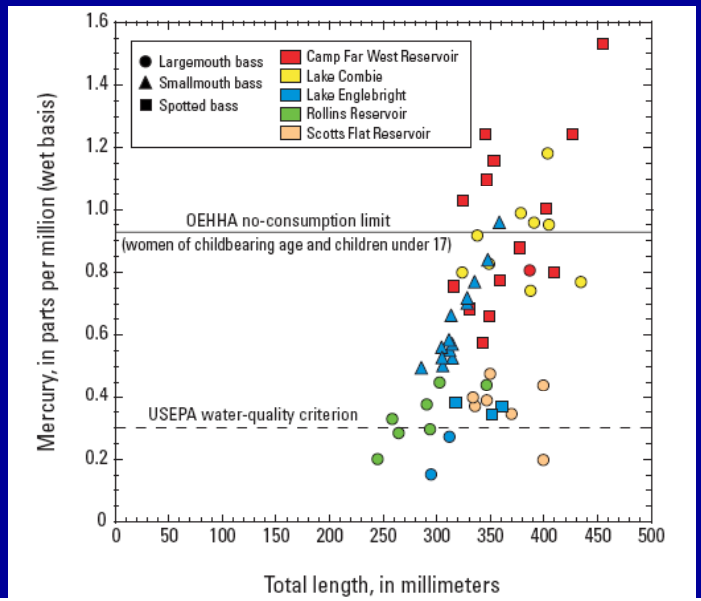
Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (1 of 3)

- Bear River (USGS / SWRCB / BLM / FS / NCRCD):
  - Fish tissue data → public health advisories
  - Load estimates for Hg, MeHg → mass balances
  - Seasonality of MeHg in water and zooplankton



Greenhorn Creek

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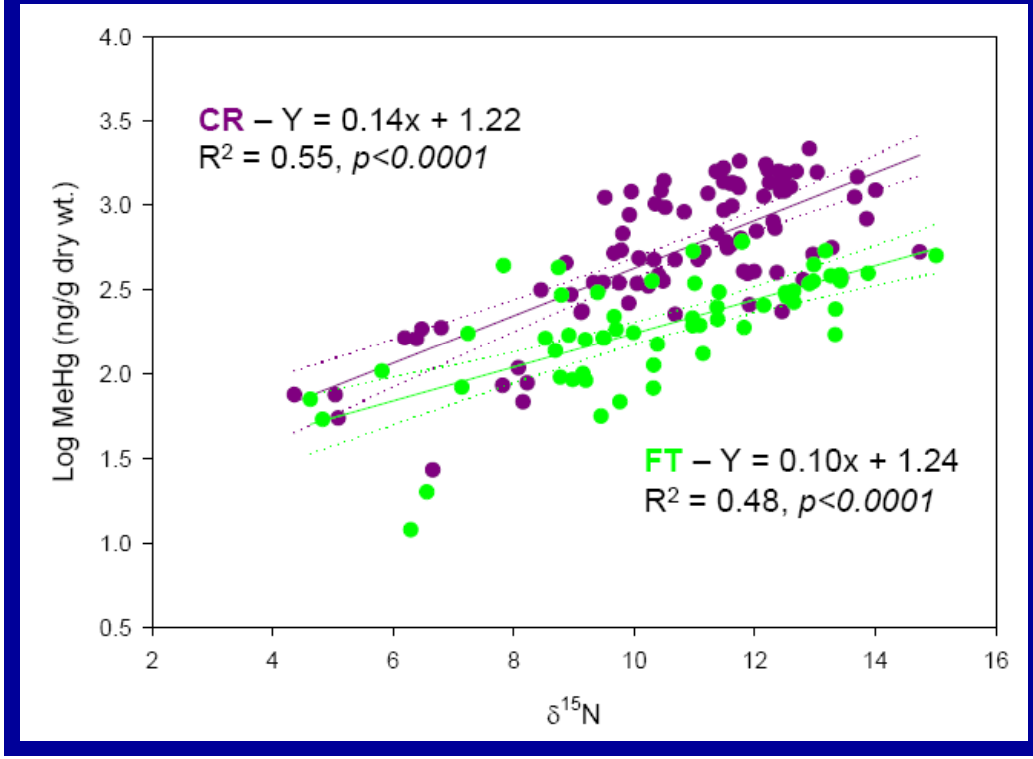
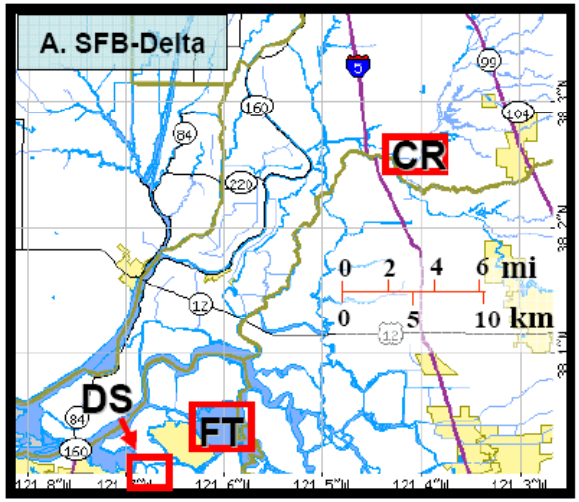
Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (2 of 3)

- Cosumnes River, Petaluma River & Central Delta (CALFED-ERP):
  - Higher MeHg (water, sediment, and biota) in Cosumnes R. and Petaluma R. compared to Central Delta





A. SFB-Delta: Map showing the three sampling regions: Frank's Tract (FT), Dutch Slough (DS) and Cosumnes River (CR).

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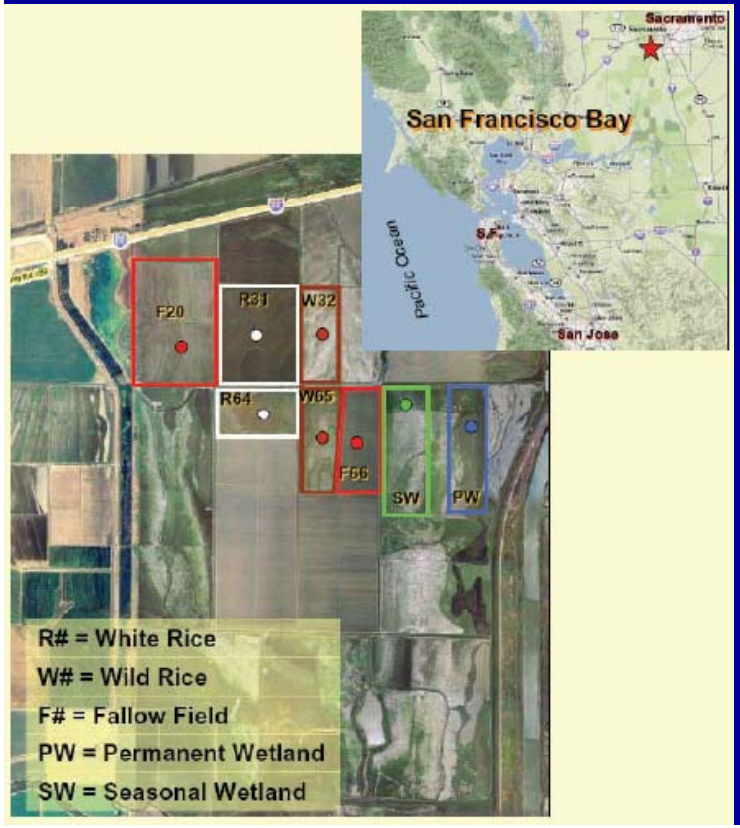
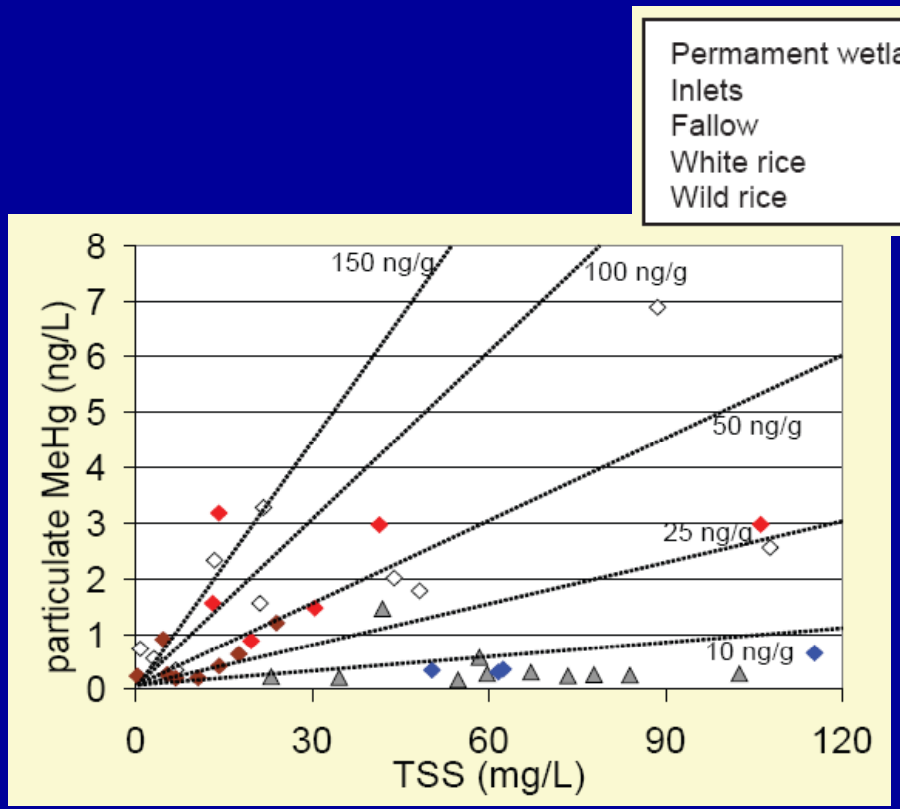
Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (3 of 3)

- Yolo Bypass (USGS / SWRCB / CDFG / SJSF):
  - First detailed study of Hg methylation and bio-accumulation in rice fields & non-agricultural wetlands





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Ecological Effects of Mercury

- SF Bay studies show negative effects of Hg on bird survival
  - Black-necked stilt – Hg higher in dead chicks
  - Forster's tern – Hg higher in eggs that fail to hatch
    - Nearly 60% of breeding population at high risk from Hg
  - Effects of Hg on many other bird species that breed in SF Bay and Delta not yet studied
  - Toxicity thresholds for Hg not established
- Data needed on fish, mammals & reptiles

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High-Priority Information Gaps

1) Arsenic speciation and bioavailability
   - Mine wastes and natural deposits
2) Mercury contamination in dredged materials
   - Spoils from historic gold dredging, settling basins, reservoirs, shipping channels, flood control
   - Suction dredging impacts in contaminated rivers
   - BMPs to minimize releases of Hg and MeHg
3) Mercury cycling in agricultural environments
4) Mercury in atmospheric deposition
   - Uncertain contribution to reactive Hg loads
5) Mercury in fish and birds
   - Data for additional public health advisories
   - Assessment of ecological effects
   - Long-term monitoring to assess trends

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Opportunities for Partnership and Collaboration

- USGS Cooperative Water Program
  - matches non-federal funds, ~$5M/yr in Calif.
- Other USGS programs in Water Resources, Geology, and Biological Resources
- Collaborative projects with other agencies
  - Federal: BOR, USFWS, BLM, USFS, USEPA
  - State: CALFED/CBDA, DFG, DWR, UCs, DOC/AMLU, SWRCB, RWQCBs, SNC
  - Local: RCDs, water agencies, sanitation districts, cities, counties, non-profit foundations